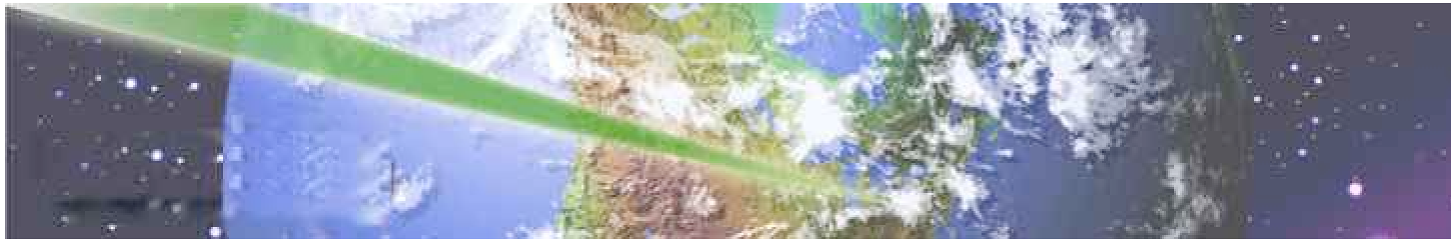

Satellite Laser Ranging Concept Review

Experience Incorporated into Replacement System

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Concept for Replacement SLR Systems

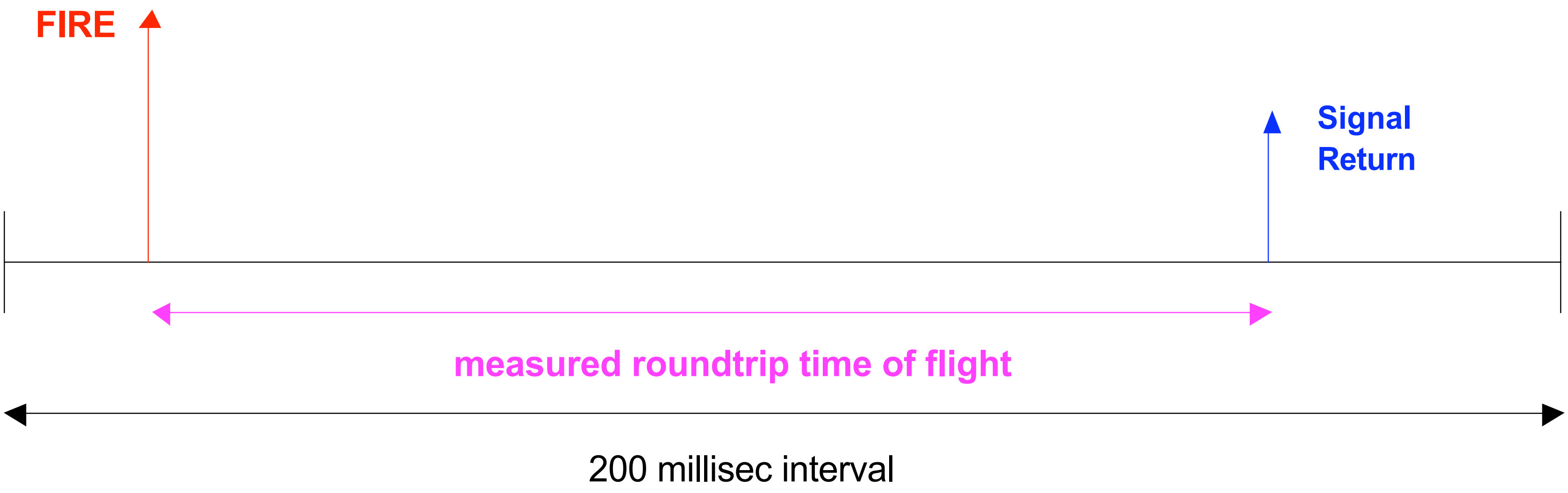
- Each station operates autonomously and independently.
- Predictions obtained via internet.
- Must perform functions of current SLR stations, plus those of the operator, and additional single photon requirements:
  - **Scheduling** based upon system performance, sky conditions, predictions, etc.
  - Separate **pointing** of transmit and receive paths,
  - **Acquisition** of satellite returns by staring and searching,
  - Determination of when satellite returns are occurring using **signal processing**,
  - **Optimization** of pointing and ranging,
  - **Calibration** of pointing (star cals) and ranging (ground cals),
  - System **safety** (intruders, weather, sun, electrical problems, etc).
- Normal Points generated from raw satellite ranges and transmitted in near real-time via internet.

New System Concept Required
Development of New Algorithms

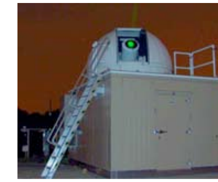
- **Single photon return capability ➔**
  - Signal detection techniques needed to distinguish signal from noise,
  - Normal Point calculations may need to be modified.
- **Narrow laser divergence ➔**
  - Separate pointing control required for transmit and receive (point-ahead).
- **Multi-kilohertz operation (with multiple fires in flight) ➔**
  - Range cannot be measured directly – reconstruct from pieces of information,
  - Laser PRF must be steered to prevent collision of transmit with return pulse.
- **Automation ➔**
  - System must be able to search for and acquire target,
  - Closed-loop tracking must be performed using QMCP,
  - Real-time scheduling requires sky information from thermal IR camera.

Range Measurements in Current SLR

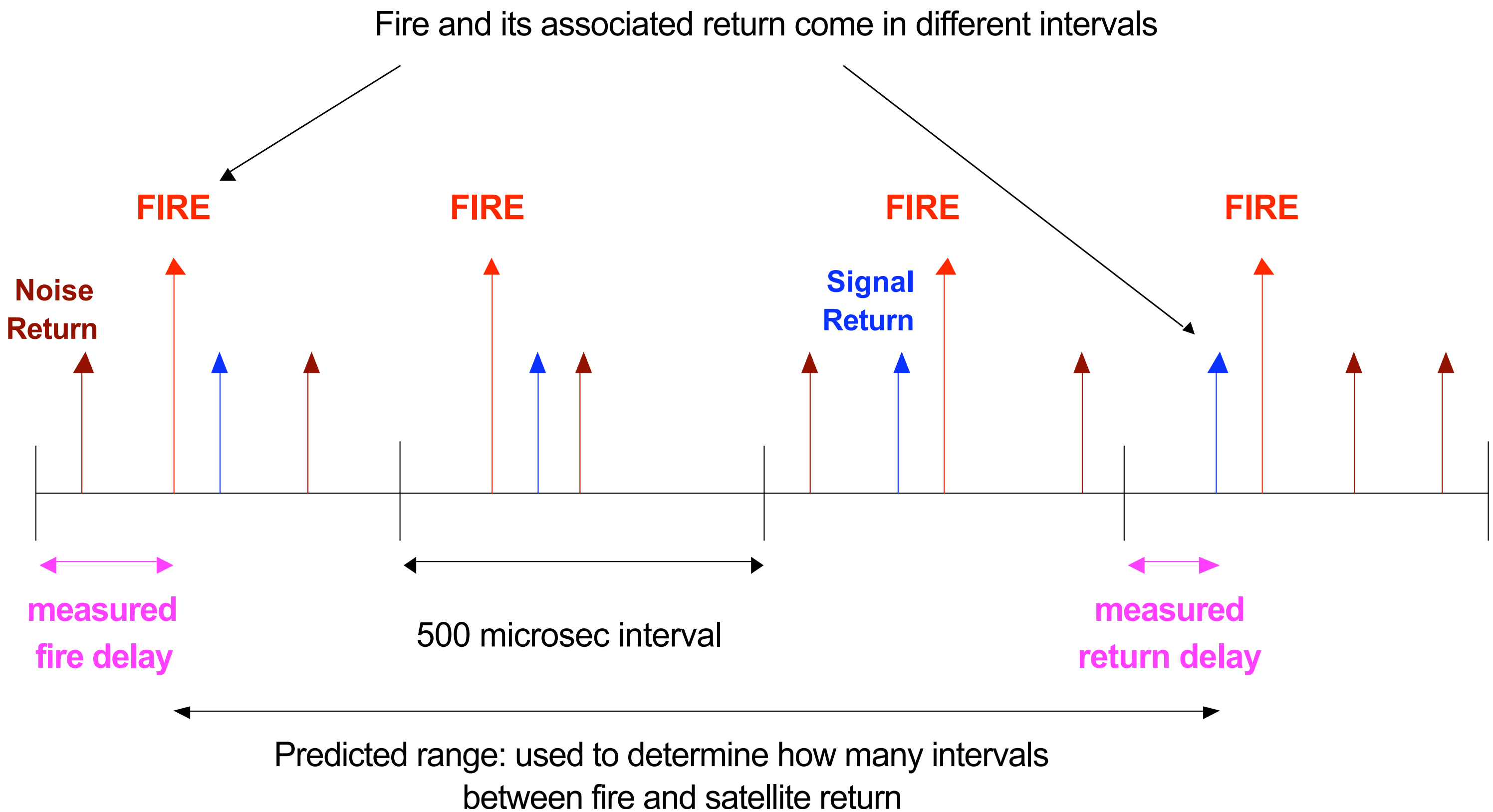
In current NASA SLR only one pulse in flight at a time. Range is measured directly by TIU.



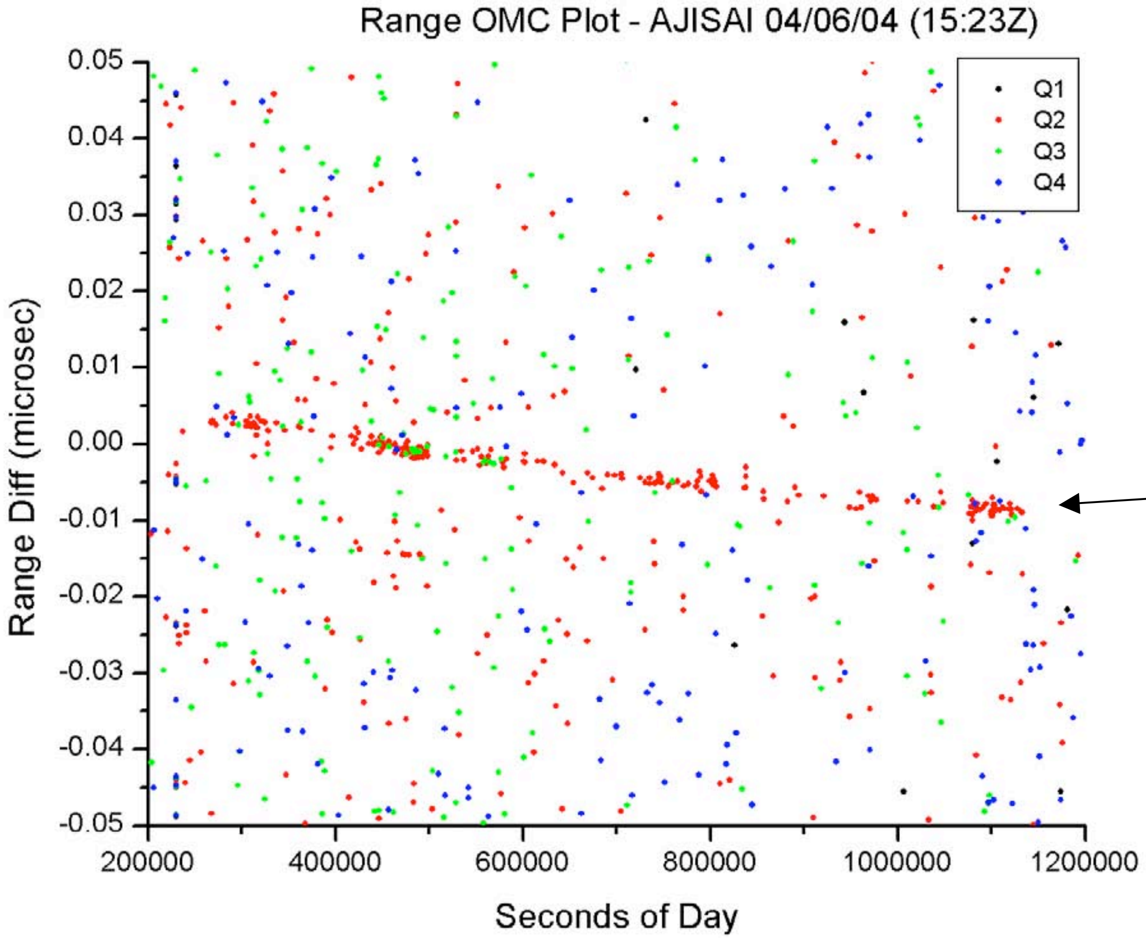
New Algorithm: Reconstruction of the Range



In new SLR many pulses in flight at same time require range reconstruction from pieces of measured information.



New Algorithm: Extraction of Signal from Noise

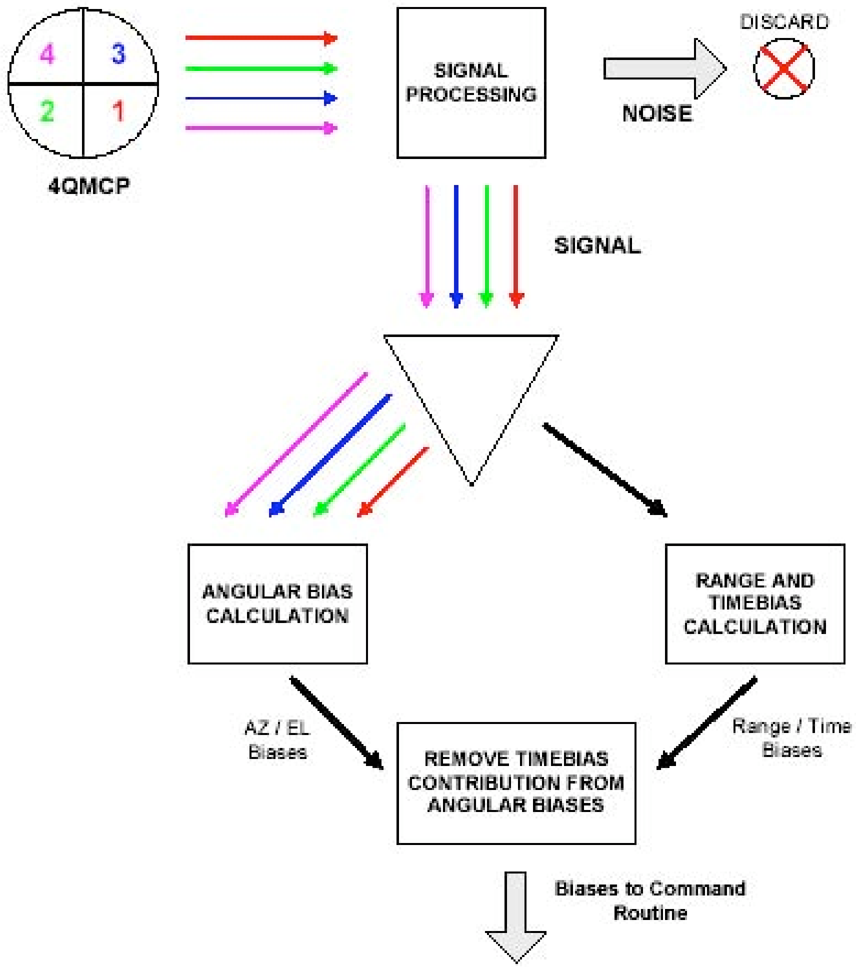


SLR2000 AJISAI pass: Satellite returns form straight line. Noise follows Poisson statistics and is randomly distributed.

Satellite Returns

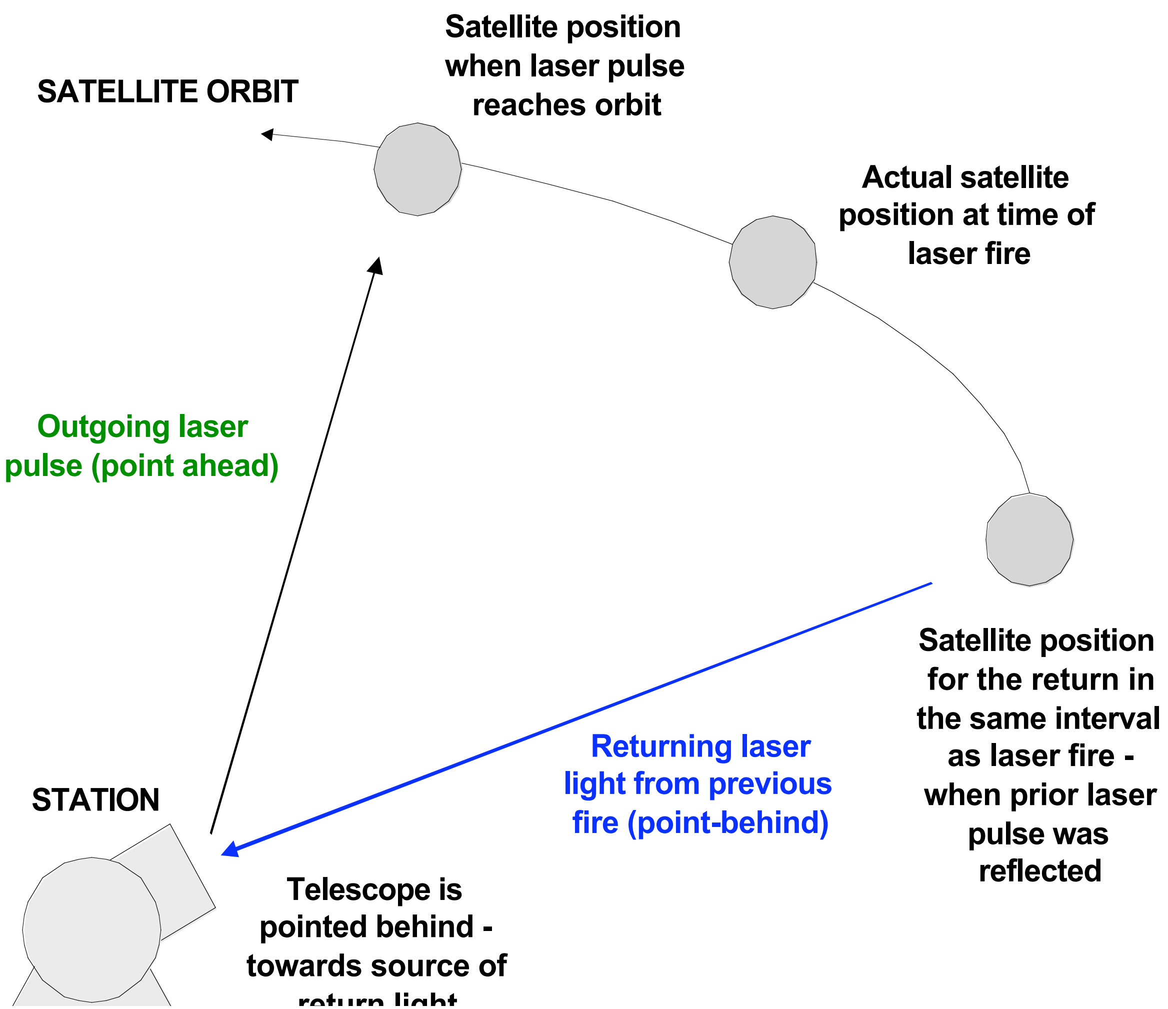
In current SLR systems the operator visually determines signal.

New Algorithm: Closed Loop Tracking to Optimize Ranging



- Quadrant MCP information is processed to extract signal.
- Signal count in each quadrant is used to compute angular biases.
- Reconstructed roundtrip range information is used to calculate range and time biases.
- In current SLR systems the operator applies biases and peaks up on return signal strength.

New Algorithm: Point Ahead needed due to narrow divergence & FOV



- Telescope points toward returning light from previous fire.
- Narrow laser divergence implies laser must be pointed ahead of satellite.
- Current MOBLAS systems point laser & telescope ahead - wide receiver field of view is able to see returns.

New Algorithm Status

- **All have been designed, analyzed and most tested in simulation.**

- **All have been coded in the SLR2000 software.**

- **Algorithm testing using SLR2000:**
  - **Range Reconstruction**: complete
  - **Signal Processing**: complete for fixed parameters
  - **Point ahead**: tested on visual tracks – not yet tested with laser
  - **Laser PRF steering**: not yet tested
  - **Closed loop tracking**: tested in simulation and at 1.2m telescope
  - **Real-time scheduling**: testing in progress
  - **Normal point calculations**:

    Software has been tested using MOBLAS-7 data. Need to evaluate NP algorithm on single photon data.

SLR2000 Prototype Importance

- Algorithms are being tested and refined with actual hardware.
- Operational conditions are used to check automation concepts.
- New hardware, alignment and calibration techniques are being evaluated and modified.
- Requirement concepts can be validated - provides risk reduction for network build.
- Software package developed and tested here:
  - 24 man-years of effort and 100,000 lines of code,
  - can be used in whole or in part for new SLR systems to save time and money in Network Replacement effort.

SLR2000 Prototype Status

- Automated star calibrations now routinely performed:
  - 22 term mount model used (developed in-house),
  - provides ~ 2 arcsecond absolute tracking accuracy.
- System delay calculated for all four detector quadrants from ground calibrations.
- 12 satellite passes tracked with very low power laser.
- Higher power laser (closer to specifications) due in shortly.

Summary

- Many new algorithms had to be developed to support the next generation SLR system concept.
- All algorithms have been developed and coded. Many have been tested using SLR2000 and are complete. A few require more work.
- The SLR2000 prototype has proved invaluable in the checkout of the new concepts and the validation of new ideas.
- Completion of the SLR2000 technical challenges is crucial for an understanding of what will work (and what won't). Can be finished in less than one year, concurrently with development of proposal package.